University of Zurich

Department of Economics

Working Paper Series

ISSN 1664-7041 (print)
ISSN 1664-705X (online)

Working Paper No. 389

Attention and Salience in Preference Reversals

Carlos Alós-Ferrer and Alexander Ritschel

June 2021

Attention and Salience in Preference Reversals*

Carlos Alós-Ferrer† Alexander Ritschel‡
University of Zurich University of Zurich

April 2021

Abstract

We investigate the implications of Salience Theory for the classical preference reversal phenomenon, where monetary valuations contradict risky choices. It has been stated that one factor behind reversals is that monetary valuations of lotteries are inflated when elicited in isolation, and that they should be reduced if an alternative lottery is present and draws attention. We conducted two preregistered experiments, an online choice study ($N = 256$) and an eye-tracking study ($N = 64$), in which we investigated salience and attention in preference reversals, manipulating salience through the presence or absence of an alternative lottery during evaluations. We find that the alternative lottery draws attention, and that fixations on that lottery influence the evaluation of the target lottery as predicted by Salience Theory. The effect, however, is of a modest magnitude and fails to translate into an effect on preference reversal rates in either experiment. We also use transitions (eye movements) across outcomes of different lotteries to study attention on the states of the world underlying Salience Theory, but we find no evidence that larger salience results in more transitions.

JEL Classification: D01 · D81 · D87

Keywords: Preference Reversals · Eye-tracking · Salience Theory

*We thank participants at the Vienna Center for Experimental Economics Seminar, 2021, for helpful comments and discussion. The second author gratefully acknowledge financial support from the *Forschungskredit* of the University of Zurich, grant no. [FK-19-021].

†Corresponding author: carlos.alos-ferrer@econ.uzh.ch. Zurich Center for Neuroeconomics (ZNE), Department of Economics, University of Zurich (Switzerland). Blümlisalpstrasse 10, 8006 Zurich, Switzerland.

‡Zurich Center for Neuroeconomics (ZNE), Department of Economics, University of Zurich (Switzerland). Blümlisalpstrasse 10, 8006 Zurich, Switzerland.

1 Introduction

Uncovering individual preferences is fundamental for applied economics, and it is essential to allow for policy recommendations and positive analysis. In practice, different methods are used, some relying on actual choices, and others on the elicitation of monetary equivalents (see Bateman et al., 2002, for an overview of elicitation methods and how they are used in applied work). It is well-known, however, that different elicitation methods might contradict each other. This is illustrated by one of the most important anomalies in decision making under risk, namely the classical *preference reversal phenomenon* (Lichtenstein and Slovic, 1971; Grether and Plott, 1979; see Seidl, 2002 for a detailed survey). This phenomenon refers to an empirically-robust pattern of decisions under risk where decision makers provide monetary values for long-shot lotteries which are above those of more moderate ones, but then choose the latter, in contradiction with any value-based theory as Expected Utility Theory or (Cumulative) Prospect Theory.

A large literature has demonstrated the robustness of the preference reversal phenomenon and postulated different, sometimes competing, explanations (e.g., Tversky et al., 1988, 1990; Tversky and Thaler, 1990; Casey, 1994; Fischer et al., 1999; Cubitt et al., 2004; Schmidt and Hey, 2004; Butler and Loomes, 2007). The phenomenon is typically demonstrated in paradigms involving pairs of lotteries consisting of a riskier option (Figure 1; left-hand side) offering a larger prize (a long shot), called the \$-bet and a relatively safe one (Figure 1; right-hand side), called the P-bet (for "probability"). Individual preferences over such pairs are then elicited both through a choice task involving pairwise choices and by comparing valuations obtained separately for each lottery in an evaluation task eliciting (typically) stated minimal selling prices (Willingness To Accept, WTA). The anomalous pattern is that decision makers often choose the P-bet in the choice task, but explicitly value the \$-bet above the P-bet in the evaluation task, which yields a contradiction since a decision maker should be indifferent between a lottery and its certainty equivalent. In contrast, the opposite pattern of choices and evaluations occurs much more rarely.

A recent, prominent argument on the origins of the classical preference reversal phenomenon arises from Salience Theory (Bordalo et al., 2012, 2013). Essentially, it states that decision makers' attention is drawn to salient payoff comparisons, and, as a consequence, true probabilities are replaced by decision weights distorted in favor of the corresponding states of the world. For this argument, it is essential that salience is determined by the visible outcomes. In the choice task both lotteries are present, while in the evaluation task employed in classical preference reversal experiments only the target lottery is present. Bordalo et al. (2012) assume that during evaluation the decision maker compares the lottery to an alternative of not having it with probability one ("a natural way to model the elicitation of minimum selling prices," Bordalo et al., 2012, p. 1271). This results in a distortion of the decision weights, which in turn leads to an overpricing of *both* lotteries. That overpricing is particularly strong for \$-bets,

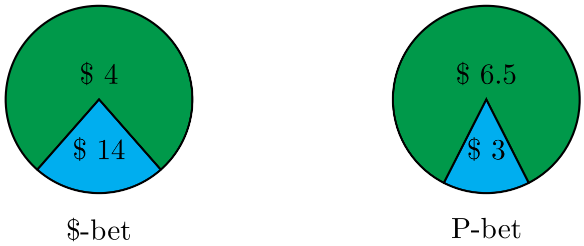

Figure 1: Two lotteries. The left lottery yields a large monetary amount with relatively low probability ($-bet) while the right lottery yields a moderate monetary amount with relatively high probability (P-bet).

because the high outcomes generate more salient states. Salience Theory suggests that reversals should be more frequent when lotteries are evaluated in isolation compared to when they are evaluated in the context of another lottery.

We conducted two preregistered preference reversal experiments, an online experiment ($N = 256$) and an eye-tracking experiment ($N = 64$), with two different treatments (varying the "salience" of lotteries) to provide direct evidence on the role of attention and salience on the classical preference reversal phenomenon. In the online study, we test the hypothesis that preference reversals should be reduced when evaluation of a target lottery happens while an alternative lottery is present. In the eye-tracking study, we additionally examine gaze data and test the hypotheses that the alternative lottery attracts attention and that this attention influences both the evaluation of the target lottery and the resulting preference reversal rates. We further observe that states of the world in Salience Theory correspond to comparisons between the outcomes of the two lotteries in a choice pair, and hence to measurable transitions (eye movements). We then use the latter to test the hypothesis that more salient states attract more attention.

The results are mixed. Neither the online nor the eye-tracking experiment revealed any effect of the presence or absence of an alternative lottery during evaluations on the preference reversal rates or on the monetary valuations of the target lotteries. However, a more detailed regression analysis of the effect of fixations revealed that, first, attention on the alternative lottery reduced both the monetary valuation of the target lottery and the likelihood of a preference reversal when the target lottery was a long shot, but not if it was a moderate lottery. This is a confirmation of the implications of Salience Theory, and in particular the prediction that evaluations in the presence of an alternative lottery should reduce overpricing.

Our analysis suggests two possible reasons for the failure of this basic effect to translate into a measurable difference in preference reversal rates. On the one hand, the effects are modest. The alternative lottery receives a relatively small number of fixations, and the effect of a fixation on the valuation of the target lottery is of a small magnitude. On the other hand, there are countervailing effects. When the target lottery is a moderate one (P-bet) instead of a long shot, attention to the alternative lottery *increases* the likelihood of preference reversals, in alignment with the view that it should also reduce the overpricing of moderate lotteries. Bordalo et al. (2012) argued that salience should indeed impact monetary valuations of both types of lotteries, but that the impact on long shots should be proportionally larger. Our data suggests that the relative difference in overpricing across lottery types is too small to have a large impact on reversal rates.

Conceptually, our studies contribute to the literature examining the consequences and implications of attention and salience for economic decisions, and in particular Salience Theory as put forward by Bordalo et al. (2012, 2013). Methodologically, we add to the small but growing literature directly examining eye-tracking measurements in economics (e.g., Knoepfle et al., 2009; Reutskaja et al., 2011; Polonio et al., 2015; Devetag et al., 2016; Polonio and Coricelli, 2019; Alós-Ferrer et al., 2019), and in particular in decisions under risk (e.g., Glöckner and Herbold, 2011; Ludwig et al., 2020; Alós-Ferrer et al., 2021).

This paper is structured as follows. Section 2 briefly reviews Salience Theory. Section 3 presents the design and results of the online experiment. Section 4 presents the design and results of the eye-tracking experiment. Section 5 discusses additional tests and comparisons. Section 6 concludes.

2 Salience Theory

Bordalo et al. (2012, 2013) proposed a theory of context-dependent choice where salient outcomes draw more attention than others, resulting in distorted decision weights. For simplicity, in this manuscript, we will refer to it as *Salience Theory.* Unlike other theories relying on distorted weights, as e.g. Prospect Theory (Kahneman and Tversky, 1979; Tversky and Kahneman, 1992), Salience Theory makes those dependent on the outcomes themselves, and, specifically, on their salience relative to the outcomes of other available alternatives.

For binary choices under risk as those considered here, Salience Theory can be summarized as follows. There is a finite set of states of the world, S. Each state $s \in S$ has an objective probability $\pi_s \in [0,1]$, so that $\sum_{s\in S} \pi_s = 1$. The decision maker chooses among two lotteries L_a, L_b, where each lottery $i = a, b$ gives a payoff $x_s^i \in \mathbb{R}$ in state s. Assume for simplicity that, for each i, $x_s^i \neq x_{s'}^i$ for all $s, s' \in S$, that is, lotteries are non-degenerate in the sense that different states result in different payoffs. Then, every state $s \in S$ is associated with one and only one pair of payoffs (x_s^a, x_s^b). That is, the set of states can be identified with the Cartesian product of the sets of outcomes of the lotteries. This is highly consequential for our purposes, because it creates a one-to-one mapping between the underlying states of the world that Salience Theory is built upon, and comparisons between outcomes of different lotteries (and thus eye movements). Consider, for instance, the binary choice depicted in Figure 2, which is based on the actual representation used in our experiments. The left lottery L_a pays \$ 4.0 with probability 0.77 and \$ 14.0 with probability 0.23. The right lottery L_b pays

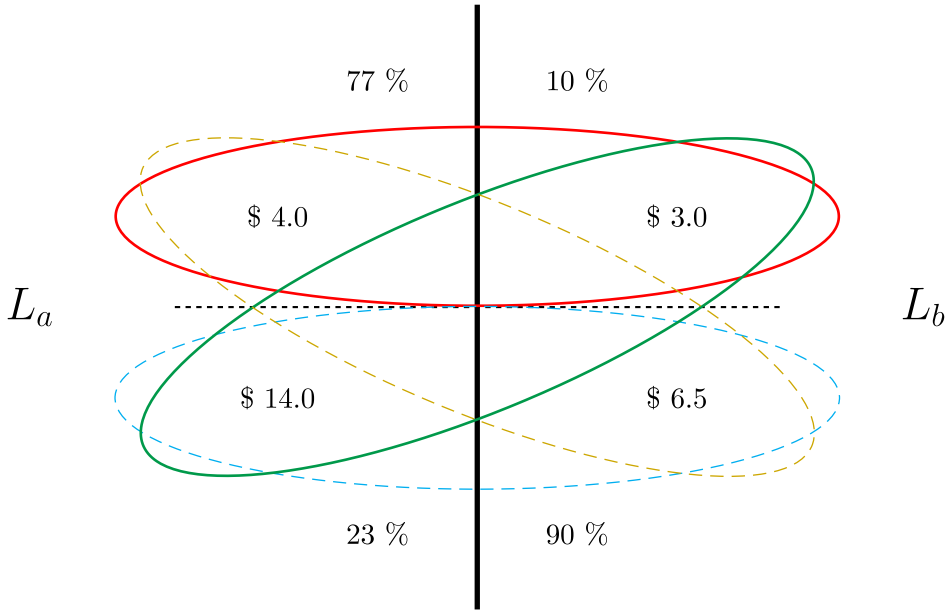

Figure 2: Schematic representation of binary choice. Salience theory's states are one-to-one with the possible transitions comparing particular outcomes across lotteries.

$ 3.0 with probability 0.1 and $ 6.5 with probability 0.9. Lotteries are independent. In Salience Theory, this corresponds to a set of four states s_1, s_2, s_3, s_4, with probabilities $\pi_1 = 0.077$, $\pi_2 = 0.693$, $\pi_3 = 0.023$, and $\pi_4 = 0.207$, respectively. State s_1 corresponds to the payoff vector $(x^a_{s_1}, x^b_{s_1}) = (4, 3)$, and so on. As seen in the figure, each state is uniquely identified by a comparison of two outcomes, one for each lottery, and thus one could write, abusing notation, $s_1 = (4, 3)$, $s_2 = (4, 6.5)$, $s_3 = (14, 3)$, and $s_4 = (14, 6.5)$.

Salience Theory predicts that choices reflect maximization of a value function

$$V^{ST}(L_i) = \sum_{s \in S} \frac{\delta^{k^i_s} \pi_s}{\sum_{r \in S} \delta^{k^i_r}_r \pi_r} v\left(x^i_s\right),$$

where $v(\cdot)$ is a utility of money (typically assumed to be linear in Bordalo et al., 2012), and $\delta \in (0, 1]$ is a parameter indicating the degree of distortion ($\delta = 1$ would mean no distortion). The key element capturing salience considerations are the natural numbers $k^i_s \in \{1, \ldots, |S|\}$, which indicate the *salience ranking* of the states, from most to least salient (that is, each state is assigned a different salience ranking).[1]

The salience ranking is determined through a *salience function* σ which assigns a real number (the salience) to each state s and lottery L_i, $\sigma(x^i_s, x^{-i}_s)$, depending also on the outcome of the *other* lottery $-i$ in that state. The key axiomatic assumptions on σ are *ordering*, meaning that a state should be more salient than another one if the outcomes of the former cover a larger range than those of the latter, and *diminishing sensitivity*, meaning that the salience of a state with positive outcomes should decrease if

[1]This rank-based discounting ensures analytical tractability. Bordalo et al. (2012) suggest some possible smooth extensions.

the outcomes of both lotteries are increased by the same constant (so that they become closer in relative terms; this reflect the well-known *Weber's Law*).[2] For instance, in the example depicted in Figure 2, the first property implies that state $s_3 = (14, 3)$ is more salient than each of the other three states.

Bordalo et al. (2012) further assume σ to be a continuous and bounded function, and suggest using the particular functional form

$$\sigma(x_s^i, x_s^{-i}) = \frac{|x_s^i - x_s^{-i}|}{|x_s^i| + |x_s^{-i}| + 0.1}, \tag{1}$$

which we will also rely on for some aspects of our experimental design.[3] For instance, using this function for the example in Figure 2 yields the salience ranking $k_{s_1}^i = 4, k_{s_2}^i = 3, k_{s_3}^i = 1, k_{s_4}^i = 2$.

To understand the implications of Salience Theory for the classical preference reversal phenomenon, remember that this phenomenon involves a specific, contradictory pattern where people choose a moderate lottery or P-bet (as lottery L_b in Figure 2), over a long shot or \$-bet (as lottery L_a in Figure 2) in direct binary choice, but then provide a larger monetary valuation for the \$-bet than for the P-bet. In Salience Theory, the value $V^{ST}(L_i)$ for a lottery can only be computed with reference to an alternative lottery. This is straightforward for the direct choices in a preference reversal experiment, where two lotteries are present. For the monetary valuation embedded in such experiments, where lotteries are presented in isolation, Bordalo et al. (2012) assume that the "natural way to model the elicitation" is to assume that the actually-presented lottery is compared to the alternative of not having the lottery, i.e. a virtual lottery yielding zero with probability one. By the ordering property, this results in a higher salience for the resulting states compared to the ones involved in direct choices, since the (typically strictly positive) outcomes of the other lottery in a pair are replaced with zero, leading to a larger range. For instance, evaluation of L_b in Figure 2 would involve the state $(14, 0)$ rather than states $(14, 3)$ and $(14, 6.5)$. However, since by definition the \$-bets involve a higher outcome, this results in a relatively more salient state for the high outcome of the \$-bet compared to the one of the P-bet ($(14, 0)$ compared to $(6.5, 0)$ in Figure 2), resulting in a particularly strong overpricing which might lead to a preference reversal. As pointed out by Bordalo et al. (2012), one could shut down this effect by conducting the monetary valuation of each lottery while the second lottery in the corresponding choice pair is actually present (instead of presenting the former in isolation). In this way, the salience ranking should be the same during choices and evaluations, preventing reversals. In

[2] *Ordering:* $\sigma(x_s^a, x_s^b) > \sigma(x_{s'}^a, x_{s'}^b)$ if $\min(x_s^a, x_s^b) \leq \min(x_{s'}^a, x_{s'}^b)$ and $\max(x_s^a, x_s^b) \geq \max(x_{s'}^a, x_{s'}^b)$, with at least one of the inequalities being strict. *Diminishing sensitivity:* If $x_s^a, x_s^b > 0$, for any $\varepsilon > 0$ it follows that $\sigma(x_s^a, x_s^b) > \sigma(x_s^a + \varepsilon, x_s^b + \varepsilon)$. A third axiomatic property, *reflection*, ensures that the salience ranking does not switch between gains and losses and is not relevant for our purposes (since all our lotteries will involve gains only).

[3] The constant 0.1 in the denominator avoids problems with zero outcomes and was proposed in Bordalo et al. (2012, Supplementary Material).

other words, Salience Theory predicts that the classical preference reversal phenomenon should occur if lotteries are evaluated in isolation, but not if they are evaluated in the context of another lottery while keeping the salience of states constant. Bordalo et al. (2012) reported data from a particular choice pair, where the monetary valuation of the \$-bet decreased when conducted immediately after seeing it next to another lottery, compared to its evaluation when presented later and in isolation.

3 Online Experiment

3.1 Design and Procedures

We conducted an online experiment using Qualtrics (preregistered at the AEA RCT Registry; see next subsection). The sample size of $N = 256$ was determined by a power analysis expecting a small-to-moderate effect size (Cohen's $d = .35$) for a one-sided non-parametric test for a between-subject design. The average earnings were £ 4.15 and the experiment took on average 11.5 minutes. Participants were recruited through Prolific (Palan and Schitter, 2018).

To ensure enough variance in choices and avoid effects arising from particular lotteries, we designed a set of 32 lottery pairs, each containing a \$-bet and a P-bet (Lotteries 1–32 in Table A.1, Appendix A). The outcomes were given in experimental currency units (ECU) which were then exchanged into £ (1 ECU=£ 0.4). Each \$-bet consisted of a high monetary outcome (> 10 ECU) with a low probability ($< 45\%$) and a second, low monetary outcome, while the P-bet consisted of a moderate monetary outcome (< 10 ECU) with a high probability ($> 60\%$) and a second, lower monetary outcome. In any given lottery pair, the high outcomes of the \$-bet and the P-bet were always the highest and second-highest of the four outcomes presented in the pair, respectively. The outcome ranking for the low outcomes of the P/\$-bets varied. The construction of lottery pairs was such that the most salient state according to Salience Theory always corresponded to the comparison between the high outcome of the \$-bet and the low outcome of the P-bet (using the salience ranking derived from (1)), and the least salient state corresponded to the comparison between the low outcomes of both lotteries.

To keep the length of the online experiment within Prolific's standards, we divided the set of lottery pairs in four subsets of 8 pairs each, and each participant in the online experiment was randomly assigned to one of the subsets. That is, each participant in the online experiment faced 8 binary lottery choices and 16 evaluations (for the 16 lotteries involved in the binary choices). Choices and evaluations were interspersed.

In binary choices, the participant selected the lottery she preferred. Lotteries were presented in a circle format (see Figure 3 for an example) with outcomes and probabilities at equal distance from the center. Outcomes were always close to the horizontal axis to facilitate transitions (eye movements) between outcomes, because those correspond to the underlying states in Salience Theory (recall Section 2; this is particularly important

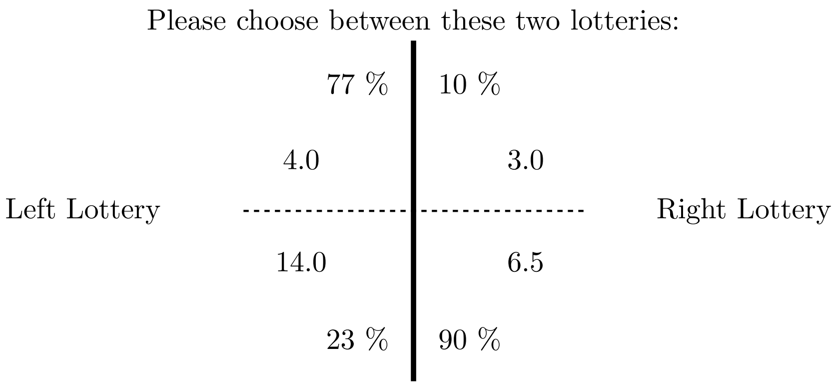

Figure 3: Choice Task. Choosing between a $-bet (here on the left) and a P-bet (here on the right).

for the subsequent eye-tracking experiment). The exact position of the outcomes (top vs. bottom) and $-bets/P-bets (left vs. right) were counterbalanced within subjects. The experiment was incentivized according to a standard procedure. Specifically, one randomly-selected decision was implemented and paid. If that decision was a choice, then the chosen lottery was played out. If that decision was an evaluation, a random selling price between the low and high outcome of the lottery was drawn. In case the price was above the stated minimum selling price, the participant sold the lottery and received the price, otherwise the lottery was played out.

We implemented two different treatments between subjects, which differed only in the evaluation phase. In the *Joint Treatment*, participants saw the lottery they were asked to evaluate while another lottery was also present (Figure 4, left). The lottery that had to be evaluated was always one of the lotteries in the choice pairs. The other lottery shown was a slightly perturbed version of the one offered in that choice pair (here a perturbed P-bet). The perturbation was such that the salience ranking remained the same as in the choice pair where the lottery was also present. The non-evaluated lottery was perturbed to avoid the exact repetition of choice pairs, which could have led to participants recognizing them and artificially enforcing consistency. In the *Separate Treatment*, participants saw the lottery that they had to evaluate, but saw black circles as placeholders where the other lottery would have been during the choice task (Figure 4, right).

3.2 Hypothesis and Result

The two treatments (Joint vs. Separate) allow to directly test the claim derived from Salience Theory that reversals should not occur when lotteries are evaluated while another lottery is present (and the salience ranking is unaltered with respect to the choice pair). The intuition is that overpricing arises because, if a second lottery is not present, the salience ranking is altered and the high outcome is then associated with a much more

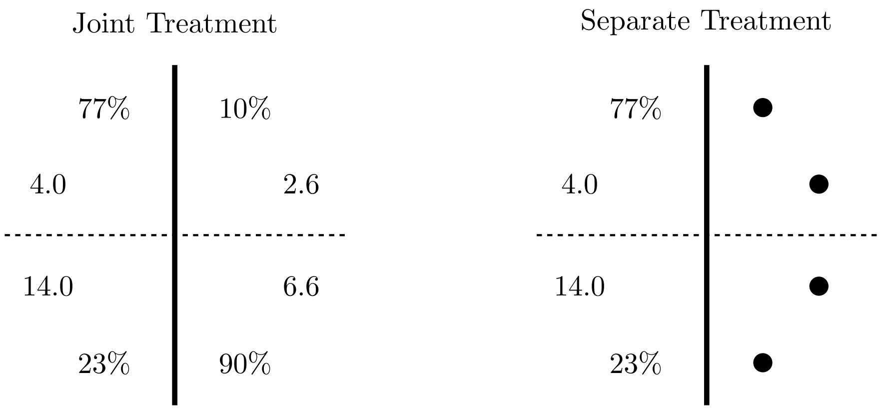

Figure 4: Treatments during Evaluation of a lottery (here left lottery). Left-hand side: Joint Treatment; right-hand side: Separate Treatment.

salient state (e.g., because it is implicitly compared to an outcome of zero for sure). The reduction in overpricing when another lottery is present during the evaluation phase should then lead to fewer reversals. Hence, we preregistered the following hypothesis (AEA RCT, Registry ID: AEARCTR-0005988):

H: Standard reversal rates should be lower in the Joint Treatment compared to the Separate Treatment (between subjects).

The standard reversal rate for a given participant is defined as the rate of $-bets being evaluated higher than P-bets conditional on the P-bet being chosen over the $-bet during the choice task. Since Hypothesis H is directional, we preregistered a one-sided Mann-Whitney-Wilcoxon test.

Figure 5 displays violin plots for the distribution of reversal rates for both treatments. For completeness, the figure also displays the non-standard reversal rates (rate of P-bets evaluated higher than $-bets conditional on the $-bet being chosen).[4] In the Joint Treatment, the average standard reversal rate was 70.28%, compared to 67.49% in the Separate Treatment. Those rates are comparable to the ones observed in the literature (Grether and Plott, 1979; Tversky et al., 1990; Cubitt et al., 2004), and in particular we reproduce the classical preference reversal phenomenon. However, contrary to Hypothesis H, we did not find lower reversal rates in the Joint Treatment than in the Separate Treatment according to the preregistered Mann-Whitney-Wilcoxon test ($N = 245$, $z = -.539$, $p = .7050$).[5]

[4]The preference reversal phenomenon is the asymmetry between standard and non-standard reversal rates (Grether and Plott, 1979; Tversky et al., 1990).

[5]All tests restricting to one of the four subsets of lotteries were also non-significant. Eleven participants never chose the P-bet, and hence their standard reversal rate is undefined.

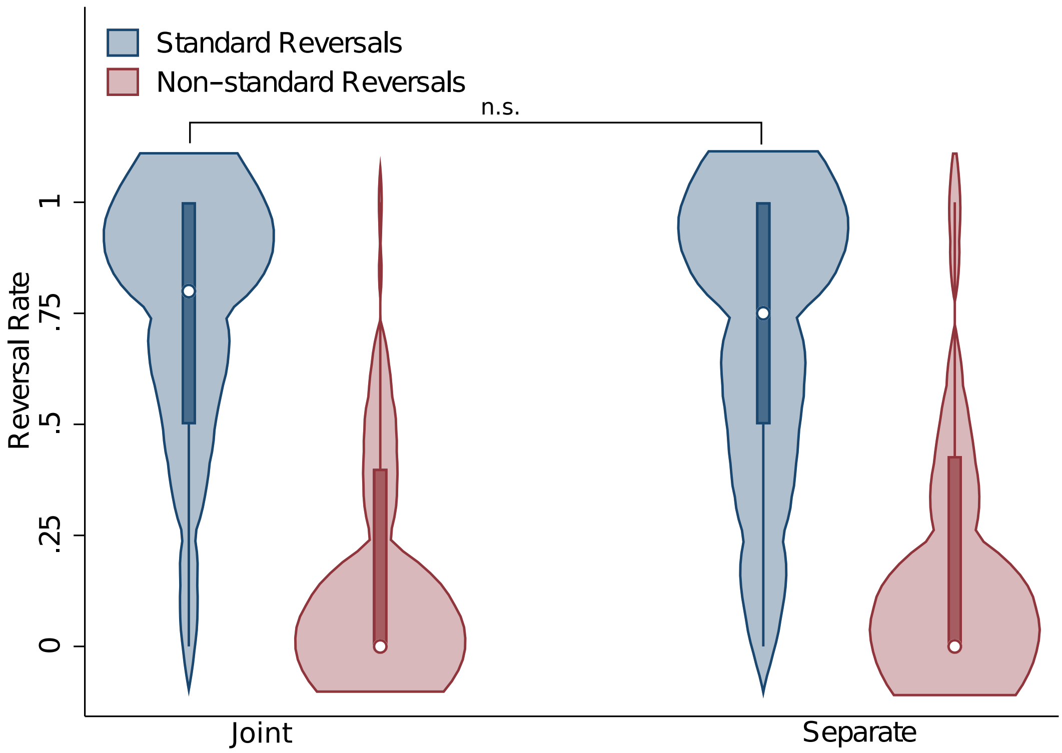

Figure 5: Reversal Rates in the Online Experiment. Violin plots depict the median, interquartile range, and kernel density plot. One-sided non-parametric test was not significant for Hypothesis H ($p > .1$).

4 Eye-Tracking Experiment

The online (purely behavioral) experiment did not find evidence for Salience Theory's prediction that changes in attention due to treatment differences should translate into differences in preference reversal rates. However, attention cannot be directly observed with just choice data. For this purpose, we turn to eye-tracking data, which allows us to infer how attention is actually distributed.

4.1 Design and Procedures

We conducted an eye-tracking experiment at the Laboratory for Social and Neural Systems Research (SNS Lab) of the University of Zurich (preregistered at the AEA RCT Registry; see next subsection). The sample size of $N = 64$ was determined by a power analysis expecting a small-to-moderate effect size (Cohen's $d = .35$) for a one-sided non-parametric test for a within-subject design. The data was collected in $N = 64$ individual sessions, each lasting around 48 minutes. Average earnings were 27.43 CHF. Lottery outcomes were given in experimental currency units (ECU) which were then exchanged into Swiss Francs (1 ECU = CHF 2.5).

The design built upon the online experiment, with a few modifications. First, each participant faced a total of 32 binary lottery choices and 64 evaluations (32 \$-bets and 32 P-bets), instead of the reduced subsets used in the shorter online experiment. Second, the two treatments were implemented within subjects, counterbalancing the lottery pairs evaluated jointly and separately across participants. That is, each subject conducted both evaluations in isolation and evaluations in the presence of an alternative lottery, but not subject evaluated the same lottery twice.[6] Third, since we did not find the reduction in standard reversals between treatments predicted by Salience Theory in the online experiment, we replaced half of the lottery pairs to give Salience Theory a better chance. Specifically, in the online experiment, lottery pairs with higher outcomes for \$-bets (pairs 17–32 in Table A.1, Appendix A) displayed a larger standard reversal rate in the Joint Treatment than in the Separate Treatment (difference of 3.11%), contrary to the prediction, while the difference was in the predicted direction (−3.13%) for the remaining lotteries. Hence, in the eye-tracking experiment, we replaced the former set of lottery pairs with pairs displaying lower outcomes for the \$-bets (pairs 33–48 in Table A.1, Appendix A). Further, one of the new pairs (nr. 47) was the exact pair used by Bordalo et al. (2012).[7]

Visual fixations were measured using a Tobii Eyelink 1000s remote eye-tracker. Participants were placed 55 cm in front of a 22" screen which showed the stimuli with a resolution of 1920×1080 pixels, and placed their heads on a chin-rest to reduce random movements. The pupil was recorded at 500 Hz and fixations were calculated by Tobii's proprietary software. The eye tracker was calibrated at the beginning of the task (after instructions) using a 9-point calibration routine. Pre-defined non-overlapping *Areas of Interest* (AOIs) were defined around every piece of information (160×90 pixels per AOI).

4.2 Hypotheses and Results

The eye-tracking experiment and all hypotheses and tests reported below were preregistered at AEA RCT, Registry ID: AEARCTR-0005985. Salience Theory implies that the presence of the other lottery changes attention and hence affects overpricing. With eye-movement data, the first natural test to conduct concerns whether the participants actually look at the other lottery. For the other lottery to affect evaluation, one would expect that participants direct some attention to it. This can be tested by comparing how often they look at that lottery in the Joint Treatment, compared to how often they look at the placeholder black circles in the Separate Treatment. Hence, we test the following hypothesis:

H1: There should be more fixations on the other lottery in the Joint Treatment than fixations on the black circles in the Separate Treatment.

[6] Each individual had her own unique sequence which determined which lottery pair was evaluated jointly or separately.

[7] We included a (new) lottery pair with a large \$-bet outcome (pair nr. 48) as an exploratory example with large differences in salience.

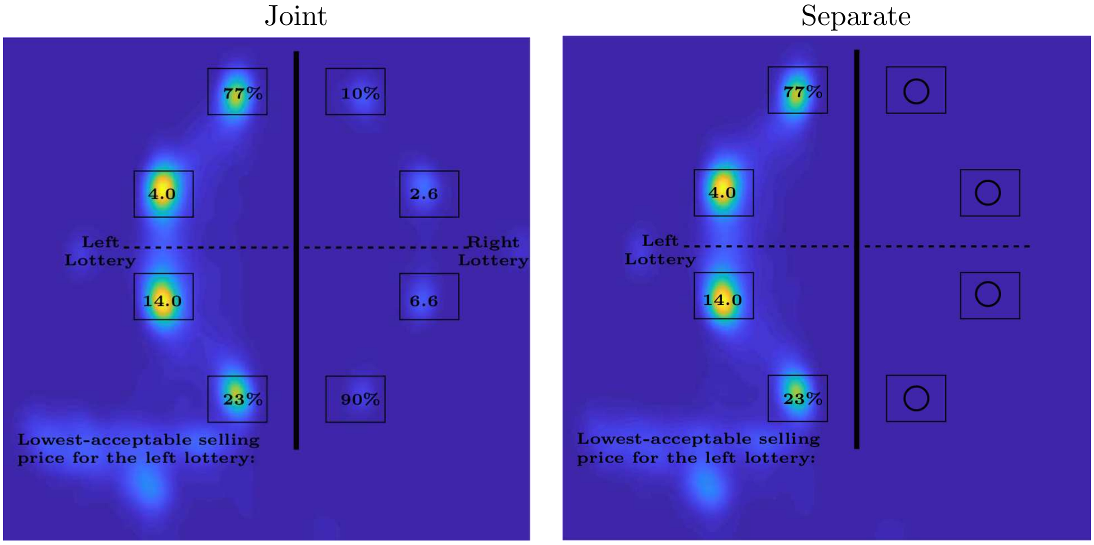

Figure 6: Heatmap of Fixations. Fixations during the evaluating the left lottery in the Joint (left-hand side) and Separate (right-hand side) Treatments. The "warmer" the colors the more fixations in the same area. Solid frames indicate Areas of Interest used for calculating the number of fixations and were not visible to participants.

Figure 6 displays a heatmap of the fixations during the evaluation task in both treatments. The "warmer" the colors, the more fixations are in a certain area. The solid frames indicate the non-overlapping AOIs used for calculating the number of fixations and were not visible to participants. We found that participants had on average 2.16 fixations on the other lottery in the Joint Treatment and only 0.08 fixations on average on the black circles in the Separate Treatment. This difference is statistically significant according to a Wilcoxon Signed-Rank test (WSR; $N = 64$, $z = 6.935$, $p < .0001$) and confirmed that, although the number of fixations is modest, participants indeed looked at the other lottery present during evaluation.

We now turn to behavior in the experiment. In accordance with Salience Theory, and analogously to Hypothesis H in the online experiment, the first hypothesis concerns reversal rates.

H2a: Standard reversal rates should be lower in the Joint Treatment compared to the Separate Treatment (within subjects).

The difference is that, in the eye-tracking experiment, we can conduct this test within subjects. Further, the test includes a different set of lotteries. Figure 7 illustrates the reversal rates in both treatments. In the Joint Treatment the standard reversal rate was 62.55%, compared to 60.47% in the Separate Treatment. As in the online experiment, those reversal rates are as commonly observed in the literature and we reproduce the classical preference reversal phenomenon. However, again as in the online experiment, and contrary to Salience Theory's prediction, we did not find lower standard reversal

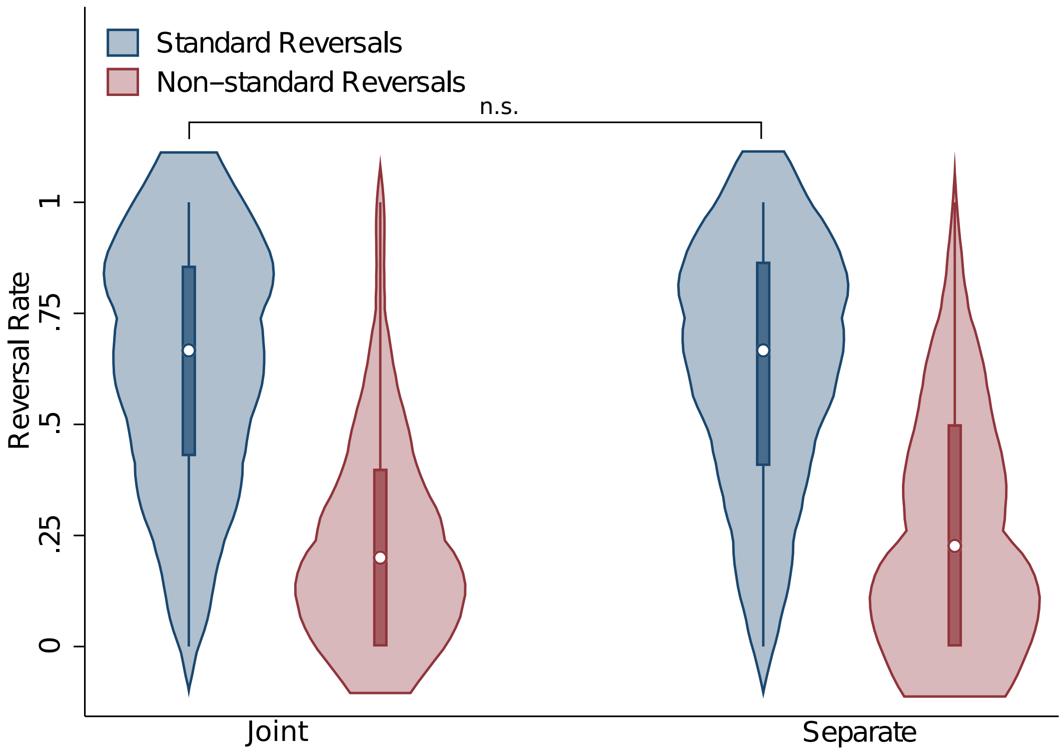

Figure 7: Reversal Rates in the Eye-tracking Experiment. Violin plots depict the median, interquartile range, and kernel density plot. One-sided non-parametric test was not significant: n.s. $p > .1$.

rates in the Joint compared to the Separate Treatment according to a Wilcoxon Signed-Rank test (WSR; $N = 63$, $z = 0.722$, $p = .7650$).

In addition to reversal rates, for the eye-tracking experiment we also preregistered hypotheses about monetary valuations. According to Salience Theory, evaluating a lottery in the context of another lottery should reduce overpricing. Following Salience Theory, we expected

H2b: The evaluations of \$-bets should be lower in the Joint Treatment compared to the Separate Treatment, when P-bets were chosen, and

H2c: the differences in lottery evaluations (\$-bets minus P-bets) should be smaller in the Joint Treatment compared to the Separate Treatment, when P-bets were chosen.

The hypotheses were conditional on pairs such that the P-bet was chosen because the standard reversal rate refers to those pairs. Figure 8 displays the evaluations of \$-bets (left-hand side) and the difference in evaluations between \$- and P-bets (right-hand side) for both treatments. The average evaluation of the \$-bet when the P-bet was chosen was 6.52 in the Joint Treatment and 6.44 in the Separate Treatment. That is, contrary to Salience Theory's prediction (H2b), \$-bets were not evaluated lower in

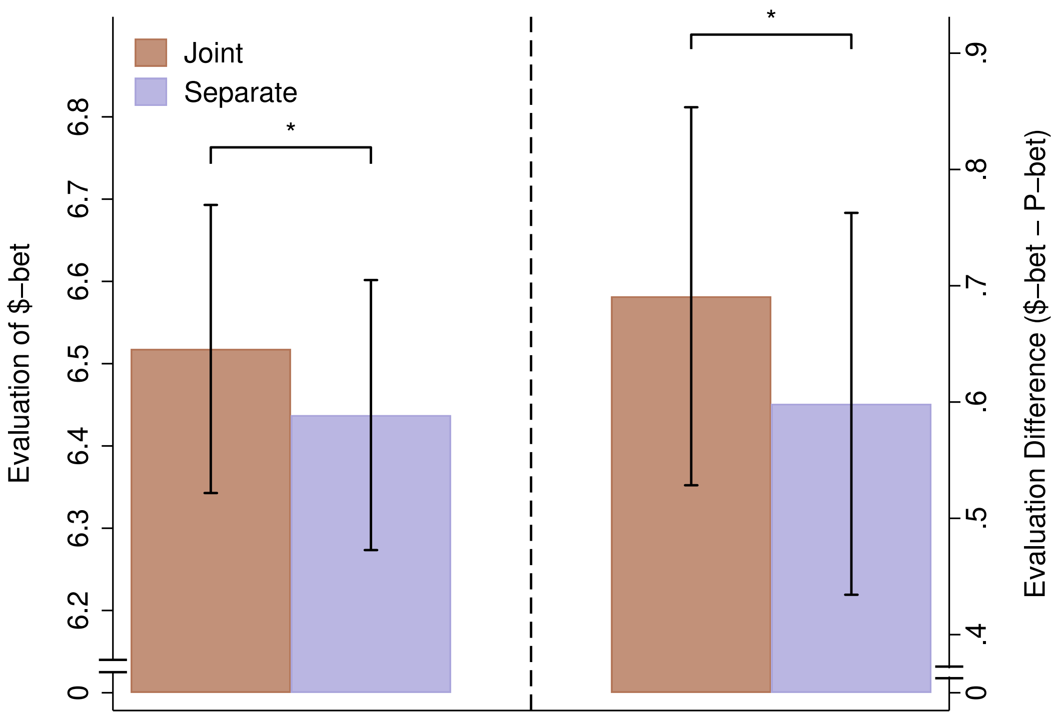

Figure 8: Evaluations in the eye-tracking Experiment. Left-hand side: Evaluation of $-bets. Right-hand side: Evaluation difference between $- and P-bets. Both comparisons are weakly significant in the opposite direction of the one predicted by Salience Theory, * $p < .1$.

the Joint compared to the Separate Treatment (WSR, $N = 63$, $z = 1.486$, $p = .9313$). In fact, our experiment found (weak) evidence in the *opposite* direction. That is, the opposite test shows that $-bets were evaluated higher in the Joint than in the Separate Treatment ($p = .0687$).

The right-hand side of Figure 8 displays the differences in evaluations between $- and P-bets, when the P-bet was chosen. The average difference in evaluations was .691 ECU in the Joint Treatment and .598 ECU in the Separate Treatment. That is, the difference between $- and P-bets was not smaller in the Joint compared to the Separate Treatment (WSR, $N = 63$, $z = 1.308$, $p = .9045$), contrary to Salience Theory's prediction (H2c). Again, our experiment found weak evidence in the opposite direction, with a larger difference in evaluations between $- and P-bets in the Joint compared to the Separate Treatment ($p = .0955$).

Behavioral data thus again failed to provide evidence for Salience Theory's predictions. The non-parametric analysis, however, does not use the additional information borne by the eye-tracking data. Rather, it simply aggregates over all observations. In the next step, we look at evaluations and preference reversals again, but control for

Table 1: Random Effects Panel Regression on Evaluations in the Joint Treatment.

Evaluation	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
# Fix. on other lottery	-0.0128	-0.0176	-0.0182*	-0.0319**	-0.0398***	-0.0399***
	(0.0105)	(0.0109)	(0.0107)	(0.0160)	(0.0173)	(0.0173)
# Fix. on evaluating lottery		0.0087	0.0071	0.0064	-0.0046	-0.0036
		(0.0058)	(0.0057)	(0.0057)	(0.0087)	(0.0087)
Evaluating a P-bet			-0.6331***	-0.7062***	-0.7100***	-0.7087***
			(0.0904)	(0.0995)	(0.0995)	(0.0994)
# Fix. other × P-bet				0.0346*	0.0322	0.0320
				(0.0197)	(0.0198)	(0.0198)
Constant	6.2023***	6.0501***	6.3978***	6.4422***	6.4878***	5.3375***
	(0.1049)	(0.1449)	(0.1520)	(0.1545)	(0.1941)	(0.7146)
Controls	No	No	No	No	Yes	Yes
Demographics	No	No	No	No	No	Yes
adj. R^2	0.0014	0.0002	0.0325	0.0354	0.0397	0.0506
WaldTest	1.49	3.79	53.05***	56.28***	59.63***	63.56***
LinCom: # Fix. other +				0.0027	-0.0076	-0.0079
# Fix. other × P-bet				(0.0160)	(0.0173)	(0.0173)
Observations	1166	1166	1166	1166	1166	1166

Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

the number of fixations on the other lottery in panel regressions. Since, according to Salience Theory, overpricing should be reduced when evaluations happen in the presence of another lottery, we should control for exactly how often the subject actually looked at the other lottery. We thus preregistered the following hypotheses.

H3a: More fixations on the other lottery should reduce the minimum selling price.

H3b: More fixations on the other lottery should reduce (standard) preference reversals.

Table 1 presents a random effects panel regression on monetary valuations in the Joint Treatment for pairs such that the P-bet was chosen in the choice phase. The coefficient of interest is "# Fix. on other lottery" in the first row, which measures the number of fixations on the other lottery (the one not being evaluated) during the evaluation phase. This coefficient thus reflects the impact of attention on the other lottery on the actual monetary valuation. According to Salience Theory, this coefficient should be negative. In the first two models, we did not find a significant coefficient. Those models, however, do not distinguish whether the evaluated lottery is a P-bet or a \$-bet. The coefficient becomes (weakly) significant when introducing a dummy taking the value one when the evaluated lottery was a P-bet (Model 3). Models 4–6 include the interaction between the number of fixations on the other lottery and the dummy. Thus, in these models the coefficient "# Fix. on other lottery" concerns the evaluation of \$-bets only. This is (highly) significant and negative, showing that fixations on the other lottery significantly reduce the evaluation of the \$-bets, as predicted by Salience Theory, by approximately 4 ECU cents (equivalent to 0.1 CHF) per fixation. In contrast, linear combination tests

Table 2: Panel Probit Regression on Preference Reversals for lotteries Jointly evaluated.

Standard Reversals	Model 1	Model 2	Model 3
# Fix. on other P-bet	-0.0482***	-0.0479***	-0.0485***
	(0.0156)	(0.0156)	(0.0157)
# Fix. on other \$-bet	0.0301*	0.0307*	0.0300*
	(0.0175)	(0.0175)	(0.0175)
# Fix. on eval. \$-bet	0.0012	0.0020	0.0027
	(0.0067)	(0.0068)	(0.0068)
# Fix. on eval. P-bet	-0.0064	-0.0058	-0.0051
	(0.0082)	(0.0082)	(0.0082)
Constant	0.3416	0.4749*	0.4782
	(0.2143)	(0.2557)	(0.8497)
Controls	No	Yes	Yes
Demographics	No	No	Yes
Log Likelihood	-351.75	-351.27	-349.20
WaldTest	12.26**	13.08**	16.87**
LinCom: # Fix. other P-bet +	-0.0180	-0.0172	-0.0185
# Fix. on other \$-bet	(0.0224)	(0.0224)	(0.0225)
Observations	583	583	583

Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

(bottom of the table, second to last row) show that fixations on the other lottery did not significantly affect the evaluation of P-bets.

We conclude that, in the Joint Treatment, fixations on the other lottery did reduce the monetary valuation of \$-bets, but the actual effect was small (about 0.1 CHF per fixation). Taking into account that the average number of fixations on the other lottery was just 2.16, the impact on monetary valuations can be seen to be rather modest. It is thus unclear whether this effect can translate into a measurable impact on preference reversals. Thus we turn to a panel probit regression with Standard Reversals as the dependent variable (Table 2), again for the Joint Treatment. That is, the dependent variable is a dummy taking the value one if the choice was in favor of the P-bet, but the monetary valuation of the \$-bet was higher than that of the P-bet, and zero otherwise. In this regression, an observation is a choice pair, which is hence associated with two different evaluations (for the \$-bet and for the P-bet in the pair), and for each of those evaluations two lotteries were displayed (Joint Treatment). Thus there are four different kinds of fixations, depending on whether they are on the actually-evaluated lottery (in turn either a \$-bet or a P-bet) or on the other, alternative lottery (which is hence either a P-bet or a \$-bet itself).

In all models in Table 2, the coefficient # Fix. on other P-bet is negative and highly significant, indicating that, indeed, standard reversals were less likely when, during evaluation of the \$-bet, the alternative lottery (hence a P-bet) was fixated more. This is aligned with the previous result that overpricing of \$-bets decreased with the number of fixations on the alternative lottery, and suggests that this indeed has an overall impact on the likelihood of reversals.

The coefficient # Fix. on other \$-bet is positive and (weakly) significant, suggesting that standard reversals were more likely with additional fixations on the alternative lottery (a \$-bet) during evaluation of the P-bet. This is also in alignment with the predictions. If fixating the alternative lottery reduces overpricing of the P-bet (and although the regression in Table 1 did not detect this effect), the result should be a reduction in the monetary valuation of this lottery. Since standard preference reversals involve the evaluation of the P-bet being lower than that of the \$-bet, this effect should translate into an increase in the likelihood of standard reversals, as observed.

Linear combination tests (bottom of Table 2) show that the negative effect of fixations on the other lottery when the evaluated lottery is a \$-bet cancels out with the positive effect when the evaluated lottery is a P-bet, and overall there is no effect on the likelihood of standard reversals.[8] This is interesting, because the intuition derived from Bordalo et al. (2012) is that salience impacts monetary valuations of both types of lotteries when conducted in isolation, but that the overall effect should result in fewer preference reversals because the impact on \$-bets should be proportionally larger. In contrast, our data suggests that the effects are relatively modest and not large enough for the relative difference in overpricing across different lottery types accruing to salience effects to actually have a large impact on reversal rates.

For the next hypothesis, recall that Salience Theory is built upon the concept of state of the world and specifically the assumption that more salient states receive more attention. Since a state corresponds to a comparison between outcomes across the two lotteries (recall Section 2), attention to this state should be reflected by the number of transitions (eye movements) between the two outcomes that the state consists of. Thus, we calculated the number of transitions for each state in each round of choice and joint evaluation.[9] Thus, the difference in attention should be the largest when comparing the most salient and least salient state for each given pair. Hence, we preregistered the following hypothesis (separately for choices and for joint evaluations).

H4: There should be more transitions between the outcomes in the most-salient state than between the outcomes in the least-salient state.

By design, in our choice pairs the most salient state was always the one corresponding to the comparison between the high outcome of the \$-bet and the low outcome of the P-bet, while the least salient state was always the one corresponding to the comparison between the low outcome of the \$-bet and the low outcome of the P-bet. During choice rounds, there were on average 0.61 transitions on the most salient state and 0.75 transi-

[8]There are no significant differences in the number of fixations on the other lottery between lottery types. See Section 5.

[9]For calculating transitions, we omitted fixations that were not in any AOI.

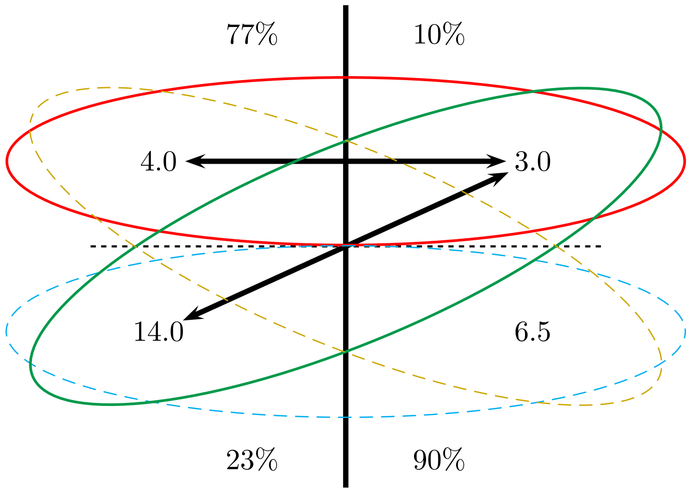

Figure 9: Transitions between outcomes representing states. Transitions encircled in green ($14.0 \leftrightarrow 3.0$) represent attention on the most salient state and transitions in red ($4.0 \leftrightarrow 3.0$) attention on the least salient state.

tions on the least salient state. There was no statistically significant evidence in favor of Salience Theory's prediction (WSR, $N = 64$, $z = -2.231$, $p = .9872$) and in fact, we find significant evidence that the least salient state received more attention than the most salient state ($p = .0128$). The same conclusion obtains for transitions during the joint evaluation rounds. Recall that there were few fixations on the alternative lottery, thus there are even fewer average transitions. There were on average 0.13 and 0.12 transitions for most-salient and least-salient states, respectively, with no significant differences (WSR, $N = 64$, $z = 0.859$, $p = .1953$).

As a robustness check, we considered transitions not only between outcomes but enlarged the area of interest to the whole *quadrant* (containing both the outcome and its probability). We confirm the previous findings for both types of rounds. Overall, there were more transitions during choice rounds. However, the most salient state (1.59) received significantly less attention than the least salient state (1.74), contrary to Salience Theory's prediction (WSR, $N = 64$, $z = -1.963$, $p = .0248$). In joint evaluation rounds, there were no significant differences in attention between most-salient (0.32) and least-salient (.31) states (WSR, $N = 64$, $z = 1.197$, $p = .1156$).

5 Exploratory Analyses

5.1 The Lottery Pair in Bordalo et al. (2012)

Our results, following our preregistered hypotheses and tests, deliver mixed evidence for the postulated implications of Salience Theory. We do find a connection between fixations and evaluations but overall we do not find the predicted reduction of reversal rates when lotteries are evaluated in the context of another one as suggested by Bordalo

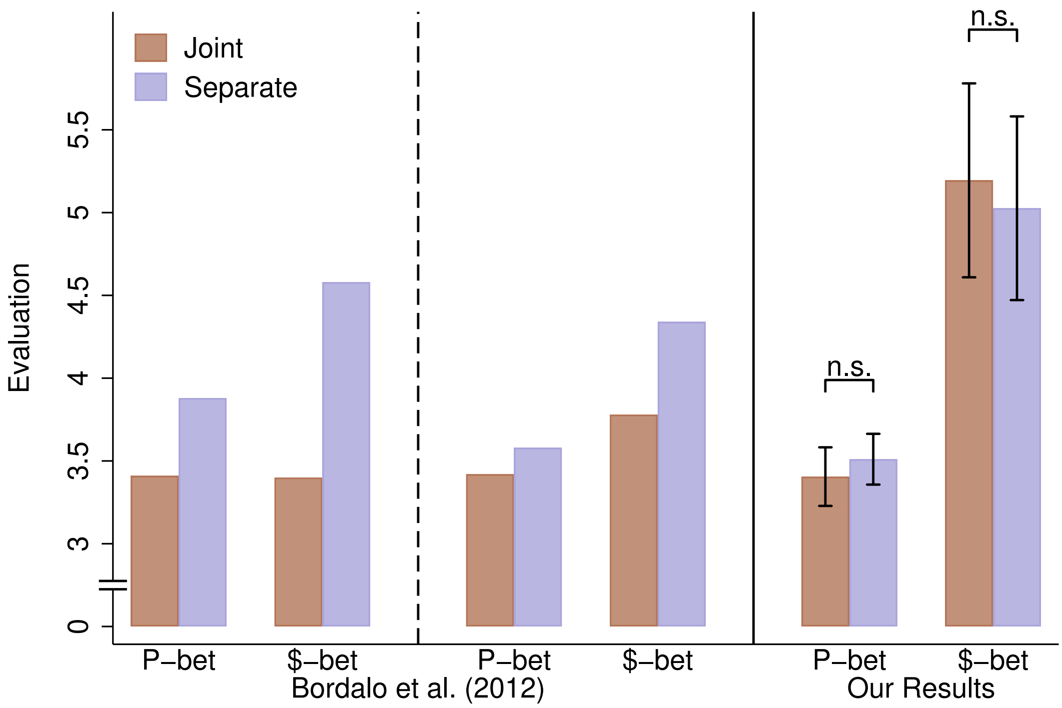

Figure 10: Evaluation of the lottery pair from Bordalo et al. (2012). Left and center panels, evaluations in the two surveys in Bordalo et al. (2012). Right panel, evaluations of the same lotteries in our eye-tracking experiment. One-sided non-parametric tests were not significant: n.s. $p > .1$.

et al. (2012). That work included a survey where each participant chose between two lotteries and immediately afterwards priced one of them (price in choice context) and after filler questions priced the other lottery in isolation. That is, the manipulation is whether the evaluation took place right after seeing both lotteries or later. Reversals conditional on the manipulation were not actually observable within subjects, since each subject priced only one of the lotteries in the pair under each manipulation. The survey employed only one lottery pair, which was one of the 32 lottery pairs we used in our eye-tracking experiment: $L_\$ = [.31, 16; .69, 0]$, $L_P = [.97, 4; .03, 0]$. A second survey using the same lottery pair followed a similar evaluation procedure but did not include an actual choice.

Figure 10 illustrates the evaluations of the lottery pair in different treatments and experiments. Bordalo et al. (2012) observed lower evaluations in the Joint Treatment than in the Separate Treatment. We, however, do not find such a difference in the evaluation for the exact same lotteries. Since the manipulations differ (actual presence of the other lottery in our case, in contrast with temporal distance in Bordalo et al., 2012), we cannot discard that the effect in Bordalo et al. (2012) might be due to a different

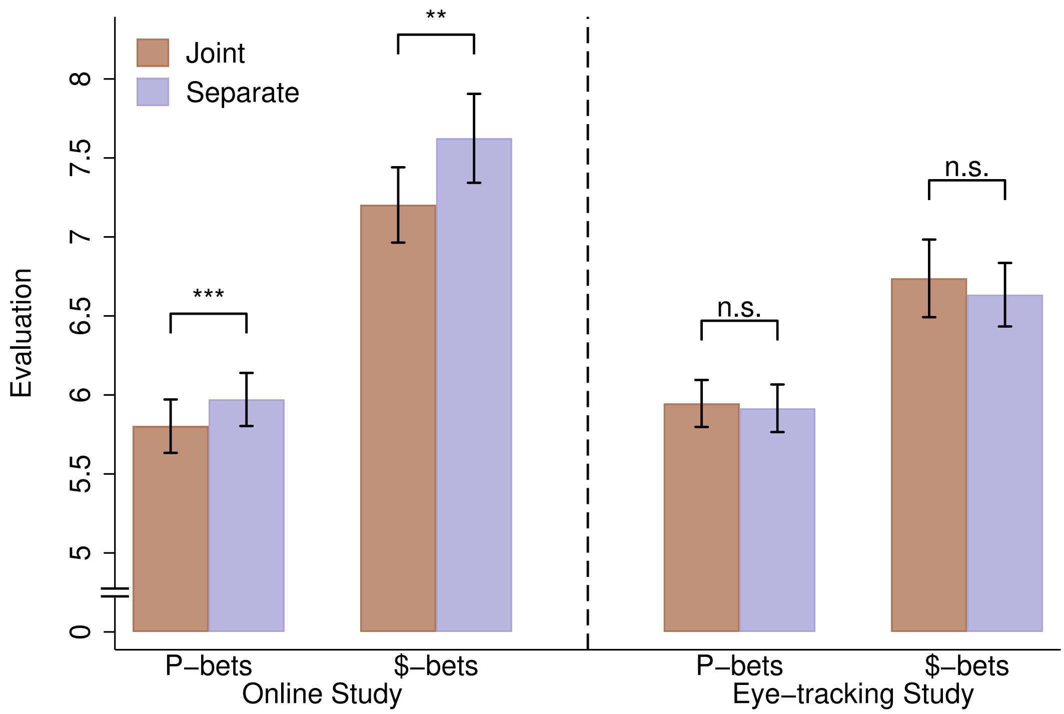

Figure 11: Average evaluation of P-bets and $-bets when P-bet was chosen during Joint and Separate evaluation treatments for the Online Study (left-hand side) and the Eye-tracking Study (right-hand side).

mechanism than whether evaluation is driven by the salience of states as derived from the comparison with another lottery.

5.2 Averages at the Lottery Level

The previous analysis of the lottery evaluations relied on subject averages across lotteries. In the following analysis, we construct an average evaluation across subjects for each given lottery, for both treatments. A Wilcoxon-Signed-Rank test then compares the evaluations between the Joint and Separate Treatments, with paired observations for each lottery. As before, the test conditions only on cases where the P-bet was chosen during the choice trials.

Figure 11 shows the average evaluation for P-bets and $-bets for both treatments for the online study (left-hand side) and the eye-tracking study (right-hand side). Results are mixed. In the online study, in line with Salience Theory's predictions, the joint evaluation did significantly reduce the stated minimum selling price compared to the separate evaluation, both for P-bets (Joint 5.80, Separate 5.97; WSR, $N = 32$, $z = 3.38$, $p = .0007$) and for $-bets (Joint 7.20, Separate 7.62; WSR, $N = 32$, $z = 2.49$, $p = .0129$). In contrast, in the eye-tracking experiment evaluations were not significantly different

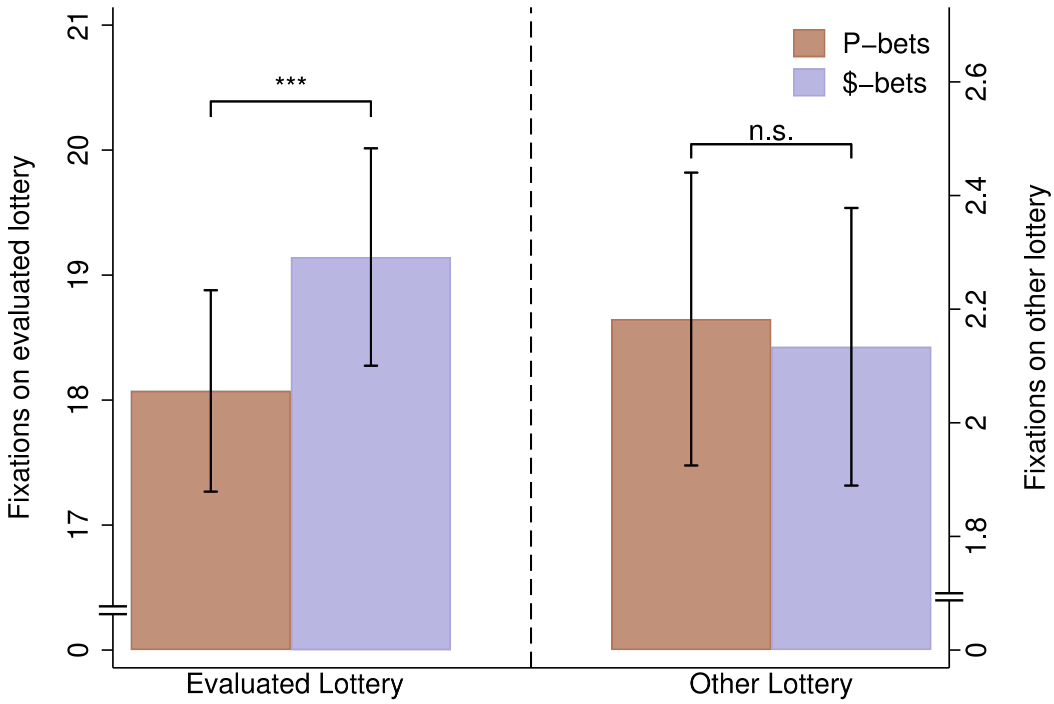

Figure 12: Number of fixations by lottery type during joint evaluation. Right-hand side shows the average number of fixations on the lottery that was evaluated. Left-hand side shows the average number of fixations on the alternative lottery, which was not evaluated.

across treatments, neither for P-bets (Joint 5.95, Separate 5.92; $N = 32$, $z = -1.103$, $p = .2699$) nor for \$-bets (Joint 6.74, Separate 6.63; WSR, $N = 32$, $z = -0.767$, $p = .4433$).

5.3 Fixations Across Lottery Types

Kim et al. (2012) and Alós-Ferrer et al. (2021) showed that fixations on P- and \$-bets differ during evaluation, with \$-bets generally being fixated more. Figure 12 shows the average number of fixations on each lottery during evaluations in the Joint Treatment, when the lottery was the one being evaluated (left-hand side), and when it was the alternative (not evaluated) lottery (right-hand side). Fixations on the evaluated lottery differed by lottery type, with P-bets being fixated significantly less often (18.07) than \$-bets (19.14; WSR, $z = 2.809$, $p = .0050$). That is, we reproduce the findings of Kim et al. (2012) and Alós-Ferrer et al. (2021) for the lottery currently evaluated. The difference, however, is absent for the alternative lottery (P-bets 2.18, \$-bets 2.13; WSR, $z = -.0281$, $p = .7787$).

Of course, the average number of fixations greatly differed between evaluated and alternative lotteries. With an average number of ≈ 2 fixations on the other lottery, it is not surprising that there are no differences across alternative lotteries of different types.

5.4 A Lottery with an Extreme Outcome

Our preregistered test for Hypothesis (H4a) in Section 4 failed to deliver evidence that differences in the salience of states are reflected by differences in the corresponding number of transitions. Lottery pair nr. 48 included a $-bet with a particularly high outcome (26 ECU) which allows us to conduct an extreme comparison along the lines of Hypothesis (H4a). Since the salience of states depends on the difference between outcomes, this pair yields a particularly large salience for the state where the high outcome of the $-bet and the low outcome of the P-bet are compared. We compare it with another pair, lottery pair nr. 2, which yields a particularly small salience for the corresponding state (in terms of (1), $\sigma(26, 2.1) = .85$ for the former and $\sigma(11.5, 5) = .39$ for the latter pair). We then test whether the high-salience state of lottery pair nr. 48 received more attention than the corresponding state of lottery pair nr. 2. This is indeed the case. During choices, subjects exhibited more transitions on the most salient state of lottery pair nr. 48 (mean 1.00) compared to the corresponding state of lottery pair nr. 2 (mean 0.39; WSR, $N = 64$, $z = 3.040$, $p = .0012$). This suggests that differences in transitions reflecting the salience of states might be generally hard to detect and only measurable when salience differences are large enough.

6 Discussion

In this work, we investigated the predictions of Salience Theory in an online experiment and an eye-tracking experiment where attention could be measured directly. We implemented two treatments which according to Salience Theory should result in differences in preference reversals.

Contrary to the predictions of Salience Theory, whether the monetary valuation for a lottery was elicited in isolation or in the presence of an alternative one failed to have any effect on the preference reversal rates or on the monetary valuations themselves. However, an analysis of the effect of fixations revealed that attention on the alternative (not evaluated) lottery reduced the monetary valuation of the target lottery, but only if the latter was a long shot ($-bet), in agreement with the view that the overpricing of long shots which is associated with the preference reversal phenomenon should be reduced if evaluations do not happen in isolation. This particular result is hence a conceptual confirmation of the implications of Salience Theory. However, the effects were small, both in terms of the attention attracted by the alternative lottery and in terms of the monetary reduction in the valuation per fixation on the other lottery. This might explain why the documented effect fails to translate into a reduction in reversal rates.

A further confirmation of Salience Theory is the fact that, in a regression analysis, the number of fixations on the alternative lottery when the target lottery was a $-bet significantly reduced the probability of a reversal. However, the number of fixations on the alternative lottery when the target lottery was a P-bet seems to increase the probability of a reversal, which is in agreement with a reduction of overpricing for the latter lottery type when evaluations are not made in isolation. These two effects appear to (at least partially) cancel out, delivering another possible reason for the absence of an effect of attention (as measured by fixations) on preference reversal rates. This echoes the discussion in Bordalo et al. (2012), which argued that salience impacts monetary valuations of both types of lotteries when conducted in isolation, but that the impact on $-bets should be proportionally larger, resulting in an effect on preference reversals. Our results suggest that the effects are modest and the relative difference in overpricing across different lottery types is too small to have a large impact on reversal rates.

We conclude that, although the evidence confirms effects of attention on monetary valuations as predicted by Salience Theory, they might be too weak to result in measurable behavioral effects, at least for the case of the classical preference reversal phenomenon.

References

Alós-Ferrer, C., A. Jaudas, and A. Ritschel (2019). Effortful Bayesian Updating: A Pupil-dilation Study. Working Paper, University of Zurich.

Alós-Ferrer, C., A. Jaudas, and A. Ritschel (2021). Attentional Shifts and Preference Reversals: An Eye-tracking Study. *Judgment and Decision Making 16*(1), 57–93.

Bateman, I. J., R. T. Carson, B. Day, M. Hanemann, N. Hanley, T. Hett, M. J. Lee, G. Loomes, S. Mourato, E. Ozdemiroglu, D. W. Pearce, R. Sugden, and J. Swanson (2002). *Economic Valuation with Stated Preference Techniques: A Manual.* Cheltenham, United Kingdom: Edward Elgar.

Bordalo, P., N. Gennaioli, and A. Shleifer (2012). Salience Theory of Choice under Risk. *Quarterly Journal of Economics 127*(3), 1243–1285.

Bordalo, P., N. Gennaioli, and A. Shleifer (2013). Salience and Consumer Choice. *Journal of Political Economy 121*(5), 803–843.

Butler, D. J. and G. Loomes (2007). Imprecision as an Account of the Preference Reversal Phenomenon. *American Economic Review 97*(1), 277–297.

Casey, J. T. (1994). Buyers' Pricing Behavior for Risky Alternatives: Encoding Processes and Preference Reversals. *Management Science 40*(6), 730–749.

Cubitt, R. P., A. Munro, and C. Starmer (2004). Testing Explanations of Preference Reversal. *Economic Journal 114*(497), 709–726.

Devetag, G., S. Di Guida, and L. Polonio (2016). An Eye-Tracking Study of Feature-Based Choice in One-Shot Games. *Experimental Economics 19*(1), 177–201.

Fischer, G. W., Z. Carmon, D. Ariely, and G. Zauberman (1999). Goal-Based Construction of Preferences: Task Goals and the Prominence Effect. *Management Science 45*(8), 1057–1075.

Glöckner, A. and A.-K. Herbold (2011). An Eye-tracking Study on Information Processing in Risky Decisions: Evidence for Compensatory Strategies Based on Automatic Processes. *Journal of Behavioral Decision Making 24*(1), 71–98.

Grether, D. M. and C. R. Plott (1979). Theory of Choice and the Preference Reversal Phenomenon. *American Economic Review 69*(4), 623–638.

Kahneman, D. and A. Tversky (1979). Prospect Theory: An Analysis of Decision Under Risk. *Econometrica 47*(2), 263–291.

Kim, B. E., D. Seligman, and J. W. Kable (2012). Preference Reversals in Decision Making under Risk are Accompanied by Changes in Attention to Different Attributes. *Frontiers in Neuroscience 6*(109), 1–10.

Knoepfle, D. T., J. T.-Y. Wang, and C. F. Camerer (2009). Studying Learning in Games Using Eye-Tracking. *Journal of the European Economic Association 7*(2–3), 388–398.

Lichtenstein, S. and P. Slovic (1971). Reversals of Preference Between Bids and Choices in Gambling Decisions. *Journal of Experimental Psychology 89*(1), 46–55.

Ludwig, J., A. Jaudas, and A. Achtziger (2020). The Role of Motivation and Volition in Economic Decisions: Evidence from Eye Movements and Pupillometry. *Journal of Behavioral Decision Making 33*(2), 180–195.

Palan, S. and C. Schitter (2018). Prolific.ac – A Subject Pool for Online Experiments. *Journal of Behavioral and Experimental Finance 17*, 22–27.

Polonio, L. and G. Coricelli (2019). Testing the Level of Consistency Between Choices and Beliefs in Games Using Eye-Tracking. *Games and Economic Behavior 113*, 566–586.

Polonio, L., S. Di Guida, and G. Coricelli (2015). Strategic Sophistication and Attention in Games: An Eye-Tracking Study. *Games and Economic Behavior 94*, 80–96.

Reutskaja, E., R. Nagel, C. F. Camerer, and A. Rangel (2011). Search Dynamics in Consumer Choice under Time Pressure: An Eye-Tracking Study. *American Economic Review 101*(2), 900–926.

Schmidt, U. and J. D. Hey (2004). Are Preference Reversals Errors? An Experimental Investigation. *Journal of Risk and Uncertainty 29*(3), 207–218.

Seidl, C. (2002). Preference Reversal. *Journal of Economic Surveys 16*(5), 621–655.

Tversky, A. and D. Kahneman (1992). Advances in Prospect Theory: Cumulative Representation of Uncertainty. *Journal of Risk and Uncertainty 5*, 297–323.

Tversky, A., S. Sattath, and P. Slovic (1988). Contingent Weighting in Judgment and Choice. *Psychological Review 95*(3), 371–384.

Tversky, A., P. Slovic, and D. Kahneman (1990). The Causes of Preference Reversal. *American Economic Review 80*(1), 204–217.

Tversky, A. and R. H. Thaler (1990). Anomalies: Preference Reversals. *Journal of Economic Perspectives 4*(2), 201–211.

Appendix A Lotteries

Table A.1: Lottery pairs: Online (1–32) and Eye-tracking (1–16, 33–48) experiment.

Lottery	$-bet				P-bet			
	High		Low		High		Low	
Pair	ECU	%	ECU	%	ECU	%	ECU	%
1	11.3	0.37	1.5	0.63	5.8	0.83	2.5	0.17
2	11.5	0.43	4	0.57	8.3	0.72	5	0.28
3	11.5	0.36	4	0.64	7.5	0.72	4.5	0.28
4	11.9	0.39	4.5	0.61	8.6	0.65	5	0.35
5	12	0.28	3.5	0.72	8	0.62	2.8	0.38
6	12	0.18	3.1	0.82	6.3	0.61	2	0.39
7	12.1	0.31	3.4	0.69	6.3	0.74	5.3	0.26
8	12.3	0.41	3	0.59	7.3	0.79	4.5	0.21
9	12.6	0.36	3.2	0.64	7.2	0.76	4.8	0.24
10	13	0.34	2	0.66	7.1	0.72	1.5	0.28
11	13.2	0.30	3.8	0.70	7.7	0.66	4.8	0.34
12	13.2	0.29	3.7	0.71	6.8	0.73	5.4	0.27
13	14	0.23	4	0.77	6.5	0.90	3	0.10
14	14	0.31	3	0.69	7.2	0.76	4	0.24
15	14	0.28	4	0.72	7.1	0.82	6	0.18
16	14.2	0.37	3.1	0.63	8.4	0.72	5	0.28
17	15	0.31	1.5	0.69	5.8	0.87	3.6	0.13
18	15.2	0.26	1.5	0.74	5.5	0.79	3.7	0.21
19	15.3	0.34	4.2	0.66	8.7	0.73	6	0.27
20	16	0.22	1.5	0.78	5.2	0.80	1.9	0.20
21	16	0.27	3.8	0.73	8.7	0.71	4	0.29
22	16.1	0.29	4	0.71	7.8	0.72	6.4	0.28
23	17.1	0.32	1.5	0.68	7.9	0.68	3	0.32
24	18.5	0.34	3	0.66	8.9	0.85	5	0.15
25	18.7	0.22	4.2	0.78	8.6	0.71	3.8	0.29
26	19	0.25	5	0.75	8.9	0.82	6	0.18
27	20	0.29	2	0.71	8.8	0.70	3.1	0.30
28	21	0.20	3	0.80	7	0.72	5	0.28
29	22	0.19	5	0.81	8.8	0.83	6.1	0.17
30	23	0.12	2.9	0.88	6	0.86	1.6	0.14
31	25.4	0.20	2	0.80	8.6	0.75	1.6	0.25
32	26	0.13	4	0.87	8.5	0.77	2.1	0.23
33	11.1	0.34	3	0.66	6.9	0.72	3.1	0.28
34	11.2	0.38	2.5	0.62	7.4	0.66	2.6	0.34
35	11.6	0.38	2.8	0.62	7.8	0.71	2.2	0.29
36	12	0.44	5	0.56	8.2	0.68	5.2	0.32
37	12.2	0.30	3.7	0.70	8.6	0.60	3	0.40
38	12.4	0.43	4.2	0.57	8.4	0.61	4.5	0.39
39	12.5	0.42	3	0.58	7.9	0.68	2.8	0.32
40	12.8	0.31	5	0.69	8.9	0.62	4.6	0.38
41	12.9	0.30	2.9	0.70	6	0.82	1.6	0.18
42	13.1	0.29	4	0.71	6.9	0.78	4.9	0.22
43	13.3	0.26	1.5	0.74	5.5	0.72	2.5	0.28
44	13.7	0.22	4.2	0.78	7.6	0.71	2.7	0.29
45	14.1	0.44	1	0.56	7	0.80	1.5	0.20
46	14.5	0.36	1.5	0.64	5.7	0.87	3.5	0.13
47	16	0.31	0	0.69	4	0.97	0	0.03
48	26	0.18	4	0.82	8.5	0.77	2.1	0.23

Appendix B Instructions

[The instructions were presented on screen. We merged the instructions of the online and eye-tracking experiment which were almost identical. Text in brackets [...] was not displayed to subjects to identify differences between treatments and/or the online and the eye-tracking experiments. Exercise trials and Comprehensions questions were only part of the eye-tracking experiment.]

General Instructions

Welcome! Thank you for participating in this eye-tracking experiment. On top of your fixed earnings of *[Online]:* 1.1 GBP / *[Eye-tracking]:* 10 CHF for completing this study, you will earn a bonus payment which will depend on your decisions.

[Online]: The bonus payment ranges from 0.6 GBP to 10.4 GBP.

Please read all instructions and questions carefully before making a decision. The experiment will take about *[Online]:* 20 minutes / *[Eye-tracking]:* 1 hour to complete.

[Online]: Answer honestly and take care to avoid mistakes.

[Eye-tracking]: The following pages explain the decision task and how your final payment is determined in detail. Use the arrow keys to navigate through the instructions. Please answer the comprehension questions at the end. In case you have any questions, please ask the experimenter.

Decisions and Payment

There are *[Online]:* 24 / *[Eye-tracking]:* 96 rounds in which you will face two types of decision tasks involving lotteries. More detailed instructions on the two decision tasks and lotteries will follow. Your bonus payment depends on the decisions you are about to make. At the end of this study, we will randomly pick one of your decisions. This particular decision will then be paid out according to the rules specified in later pages.

Each decision could be the one that counts for your bonus. It is therefore in your best interest to consider all your answers carefully.

The bonus you can earn in each decision is presented in Experimental Currency Units, in short ECU. At the end of the study your bonus payment will be exchanged using the following exchange rate:

[Online]: 1 ECU = 0.4 GBP.

[Eye-tracking]: 1 ECU = 2.50 CHF.

Lotteries

Below is an example of two lotteries: a Left Lottery and a Right Lottery, which are separated by a vertical line.

Each lottery has two outcomes that can occur with certain probabilities (both adding up to 100%). Each outcome pays a certain amount of ECU. The two outcomes of a lottery are separated by a dashed, horizontal line, i.e. there is a top and bottom outcome, each shown next to the probability of the outcome (i.e., how likely each outcome is).

⋘ *[Example Lottery (Figure B.1) was shown here]* ⋙

Example: The Left Lottery has two possible outcomes. With a probability of 29% the lottery yields 14.0 ECU and with a probability of 71% the lottery yields 3.3 ECU.

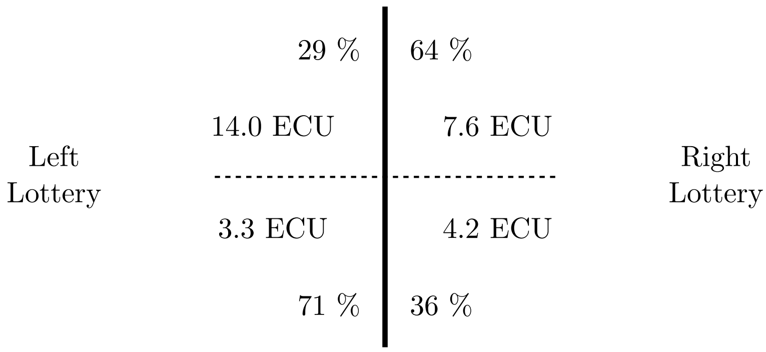

Figure B.1: *[Example Lottery shown during instructions. $-bet (here on the left) and a P-bet (here on the right).]*

Task A: Choose Between Two Lotteries

One of the tasks is to choose between two lotteries and select the one you prefer (Left Lottery or Right Lottery).

In this task you simply select the lottery you prefer to play out. Playing out the lottery means that one of the two outcomes is realized and you will earn that amount of ECU.

⋘ *[Example Lottery (Figure B.1) was shown here]* ⋙

Example: Suppose you chose the Left Lottery which yields 14.0 ECU with 29% probability and 3.3 ECU with 71% probability. Imagine a box with a total of 100 balls of which 29 are blue and 71 are orange. We will then randomly pick a ball from the box and if it is blue you will earn 14.0 ECU and if it is orange you will earn 3.3 ECU.

[Eye-tracking]: Exercise Trial: Choose Between Two Lotteries!

Use the "left Arrow" and "right Arrow" key on the keyboard to choose the "Left Lottery" and "Right Lottery," respectively.

⋘ *[Example Lottery (Figure B.1) was shown here]* ⋙

Task B: State the Lowest-acceptable Selling Price

The other kind of task you will encounter is to state the lowest-acceptable selling price for a lottery: For this, simply assume that you already own the lottery and you have to state the lowest price at which you are still willing to sell that lottery instead of keeping and playing it out.

[Eye-tracking]: In some case you will only see the lottery and black dots on the opposite side (as depicted here). In other cases both lotteries are depicted and you have to state the lowest-acceptable selling price for the indicated lottery (example depicted in the Exercise Trial).

Your bonus payment will be determined as follows:

We will randomly determine an offer for buying the lottery from you.

- If the offer is larger than (or equal to) the lowest-acceptable selling price you stated, then you sell the lottery for the amount of ECU we offered.

[Eye-tracking and Separate Treatment Online Experiment]

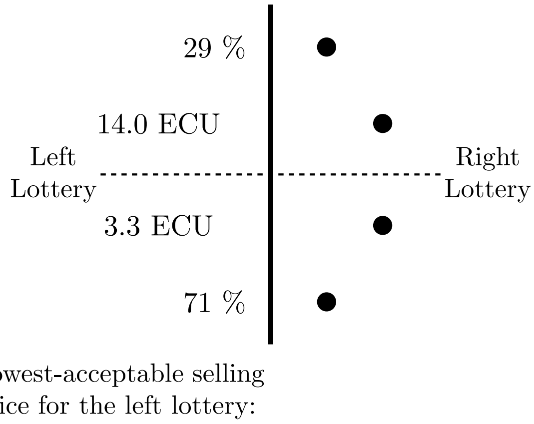

Figure B.2: *[Example Lottery of Separate Evaluation shown during instructions.]*

[Joint Treatment, Online experiment]

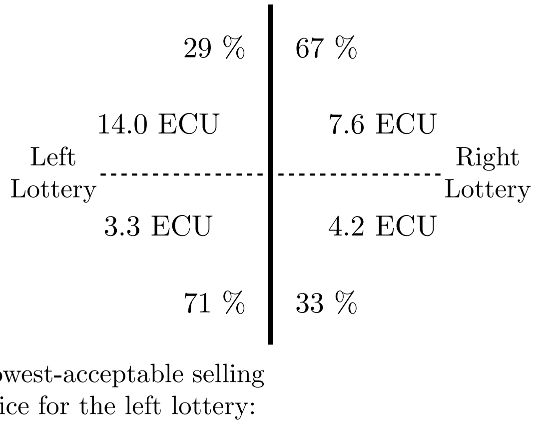

Figure B.3: *[Example Lottery of Joint Evaluation shown during instructions in the Joint Treatment in the Online experiment.]*

- If the offer is smaller, then you keep the lottery and it will be played out. This means that you will randomly receive one of the outcomes of the lottery you kept (according to the probabilities of each outcome).

⋘ *[Example Lottery Evaluation (Figure B.2 or Figure B.3) was shown here]* ⋙

Example: Suppose you stated that 6.5 ECU is the lowest-acceptable selling price for the Left Lottery.

- If we offered to buy the lottery for, e.g., 9.5 ECU (randomly determined), which is higher than your stated price, then you sell the lottery and earn 9.5 ECU.
- If we offered to buy the lottery for, e.g., 5.3 ECU (randomly determined), which is lower than your stated price, then you will keep the lottery and your earnings will be determined by playing it out.

This means that for any offer larger than (or equal to) the lowest-acceptable selling price you stated, you prefer selling the lottery instead of keeping and playing it out. For any offer below the lowest-acceptable selling price you stated, you prefer keeping and playing it out.

Therefore, it is in your best interest to truthfully report the lowest-acceptable selling price, i.e., the lowest price at which you are still willing to sell the lottery.

Note that the lowest-acceptable selling price cannot be larger than the larger outcome or smaller than the smaller outcome of the lottery.

[Eye-tracking]: Exercise Trial: State the Lowest-acceptable Selling Price!

State the lowest-acceptable selling price for the Left Lottery: Use the number pad to enter the lowest-acceptable selling price for the Left lottery and press the "Return"(/"Enter") key to confirm the price or "Backspace" to delete the currently typed price.

Use this opportunity to familiarize yourself with entering the price while keeping your gaze on the screen.

⋘ *[Example Lottery Evaluation (Figure B.2) was shown here]* ⋙

[Eye-tracking]: Comprehension Questions

⋘ *[Example Lottery (Figure B.1) was shown here]* ⋙

Comprehension Question 1: What is the probability you will receive 14.0 ECU in case the Left Lottery is played out?'

Comprehension Question 2 What is the probability you will receive 7.6 ECU in case the Right Lottery is played out?

Comprehension Question 3 What amount of ECU can you receive with probability of 71% when playing the Left Lottery?

Comprehension Question 4 What amount of ECU can you receive with probability of 36% when playing the Right Lottery?

This is the end of comprehension questions! Do you have any remaining questions? The calibration is about to start.